Compact, Engineered, 2-Micron Coherent Doppler Wind Lidar Prototype for Field and Airborne Validation

IIP-04-0072

"Doppler Aerosol WiNd lidar (DAWN)"

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Mr. Paul Petzar	SAIC	Electronic Design
Karl Reithmaier	SAIC	Opto-mechanical design

Also many thanks to Brian Killough, Keith Murray, Garnett Hutchinson, and Ken Anderson

IIP Motivation

	Mission	Measurement	Technique	Technology
Primary	Science: Weather, Climate	Earth Vertical **Wind** Profiles	Scanning Doppler Lidar	Pulsed, 2-Micron, Ho Laser
Secondary	Science: Climate	Earth Vertical **CO_2** Concentration Profiles	Scanning DIAL Lidar	Pulsed, 2-Micron, Ho Laser
	Science & Exploration: Atmos. Char., EDL	Mars Vertical **Density** Profiles	DIAL Lidar (CO_2)	Pulsed, 2-Micron, Ho Laser
	Science & Exploration: Atmos. Char., EDL	Mars Vertical **Wind** Profiles	Scanning Doppler Lidar	Pulsed, 2-Micron, Ho Laser
	Science: Climate	Earth Vertical **Aerosol** Concentration Profiles	Backscatter Lidar	Pulsed, 2-Micron, Ho Laser
	Science & Exploration: Atmos. Char., EDL	Mars Vertical **Dust** Profiles	Backscatter Lidar	Pulsed, 2-Micron, Ho Laser

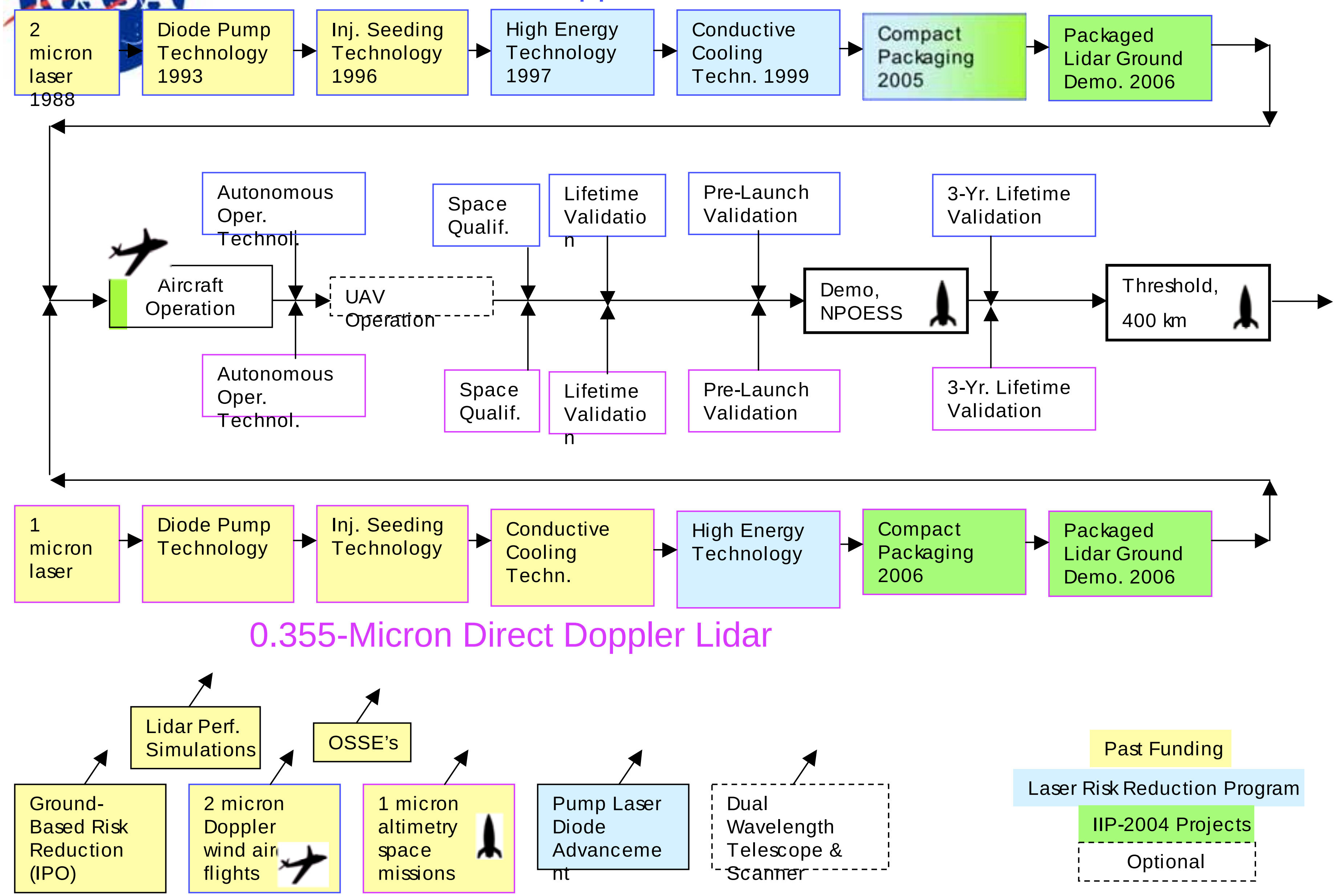
IIP Abstract

The state-of-the-art 2-micron coherent Doppler wind lidar breadboard at NASA/LaRC will be engineered and compactly packaged consistent with future aircraft flights. The packaged transceiver will be integrated into a coherent Doppler wind lidar system test bed at LaRC. Atmospheric wind measurements will be made to validate the packaged technology.

This will greatly advance the coherent part of the hybrid Doppler wind lidar solution to the need for global tropospheric wind measurements.

IIP and the Global Tropospheric Wind Profiles Roadmap

2-Micron Coherent Doppler Lidar

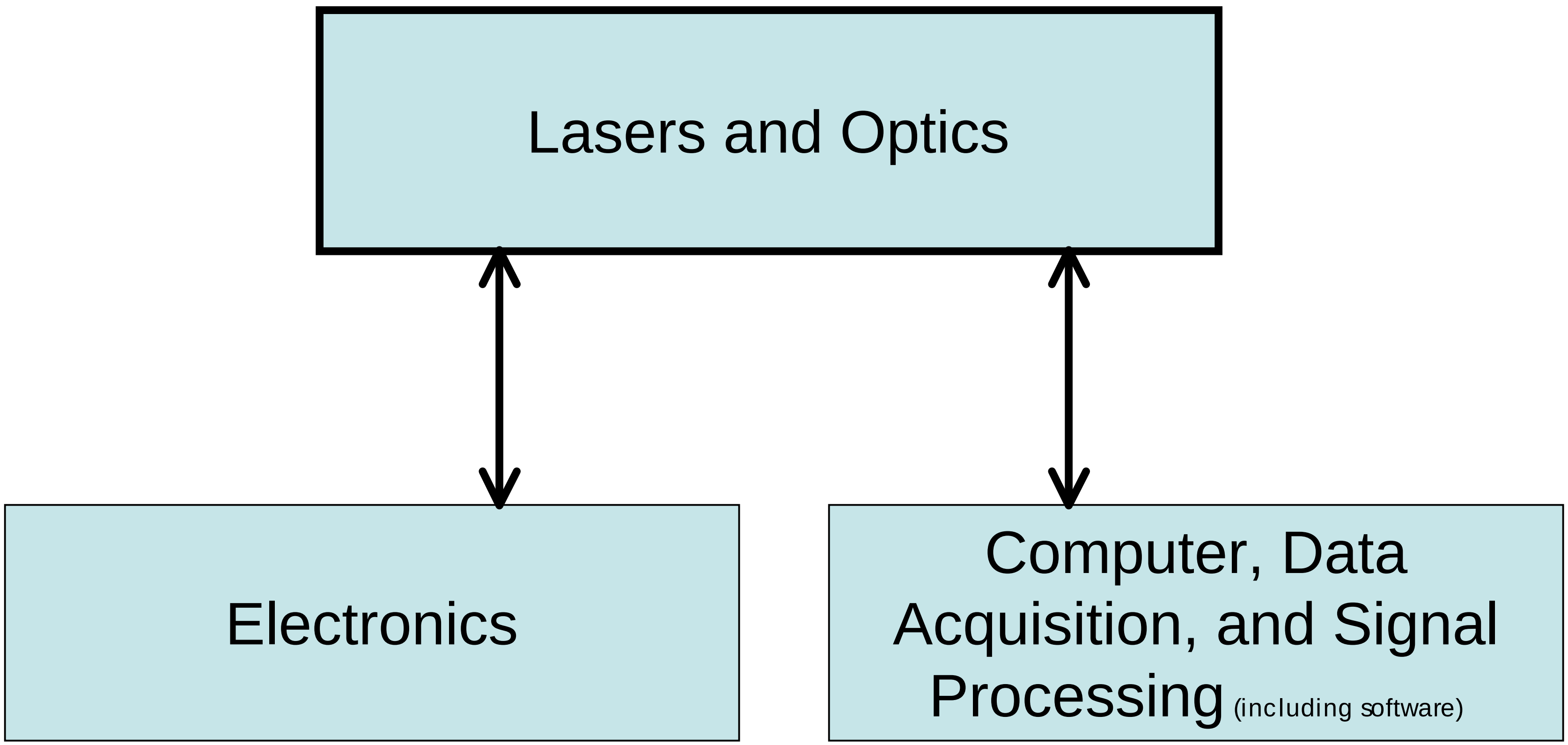


IIP and the LaRC Development of Pulsed, 2-Micron Laser Technology For Space

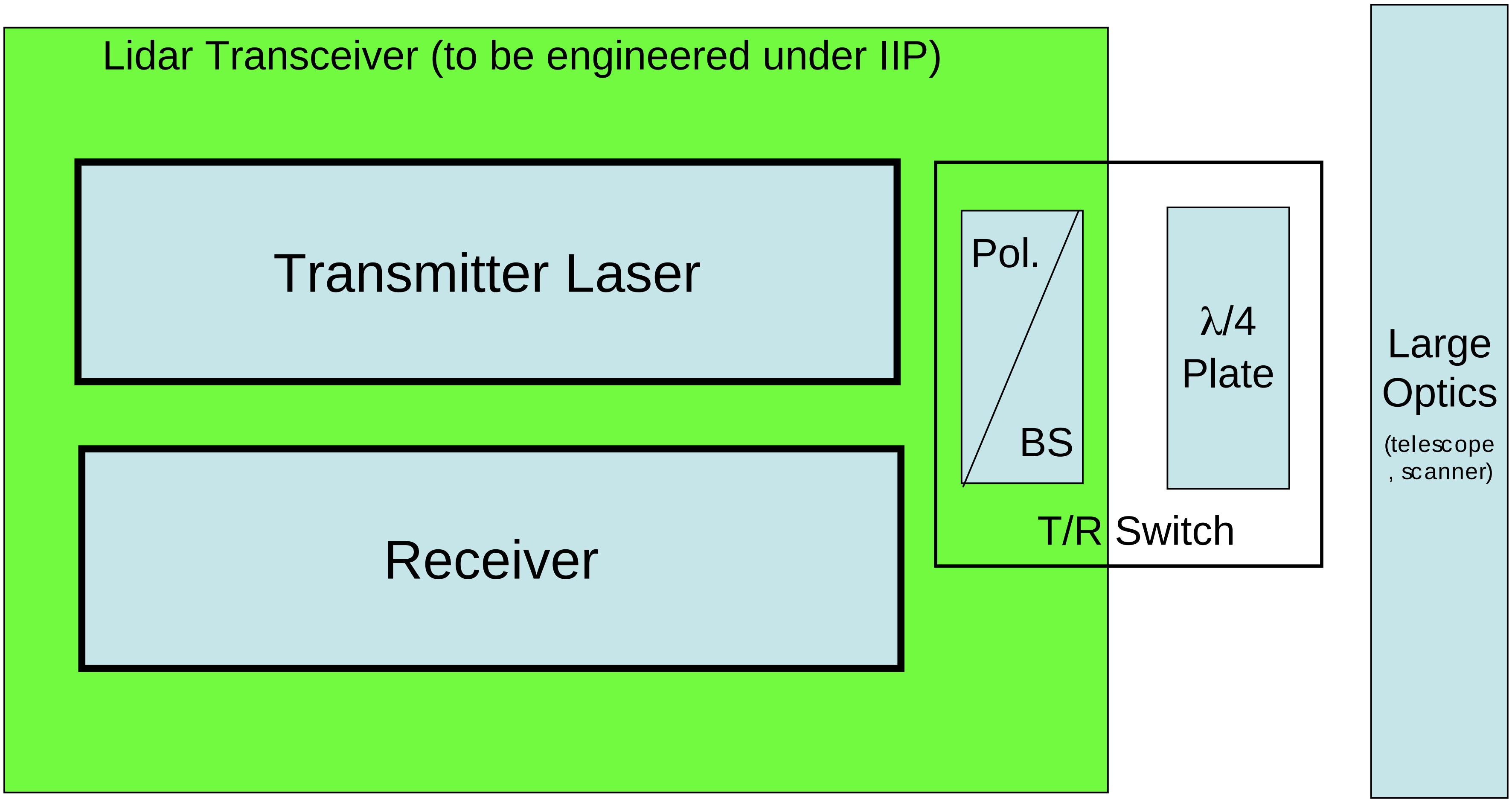
Category	Sub-Category/Date	6/02	9/02	2/03	4/03	11/03	2/05	12/05	LRRP	**IIP**	SPACE DEMO
Demonstrated (Side-Pumped, LuLiF)	Pulse Energy (J) <u>(in double pulse)</u>	0.135	0.355 /<u>0.6</u>	0.095	0.626/ <u>1.05</u>	0.1/ 0.073	1/<u>1.5</u>	1.2		**0.25**	0.25
	Pulse Rate (Hz)	2	2	10	2	2/10	2	2		**10**	5-10
	Efficiency (%) (O-O)	3.65	3.66	2.57	4.10	2.78	5/<u>6.2</u>	6.5			
Laser Component	Oscillator	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Preamplifier						✓				
	Amplifiers		1 x 2-pass		2 x 2-pass		2 x 2-pass	2 x 2-pass	✓	**1 x 2-pass**	1 x 2-pass
Laser Mode	Q-Switched	✓	✓	✓	✓	✓	✓	✓		✓	✓
	Double Q-Switched		✓		✓	✓	✓				
	<u>Injection Seeded=SLM</u>			✓						✓	✓
Cooling	All liquid				amp						
	Partially conductive	✓	✓	✓	osc		✓	✓		✓	
	All cond w/o heat pipe										
	<u>All cond w/ heat pipe</u>					✓			✓		✓
Pump Diodes	C Package				amp						
	A package	✓	✓	✓	osc	✓	✓	✓	✓		
	AA package									✓	
	<u>G package</u>										✓
Packaging	Laboratory Table	✓	✓	laser	✓	laser	✓	✓			
	<u>Compact, Engineered</u>			head		head			head	✓	✓

IIP – Scope of the Effort

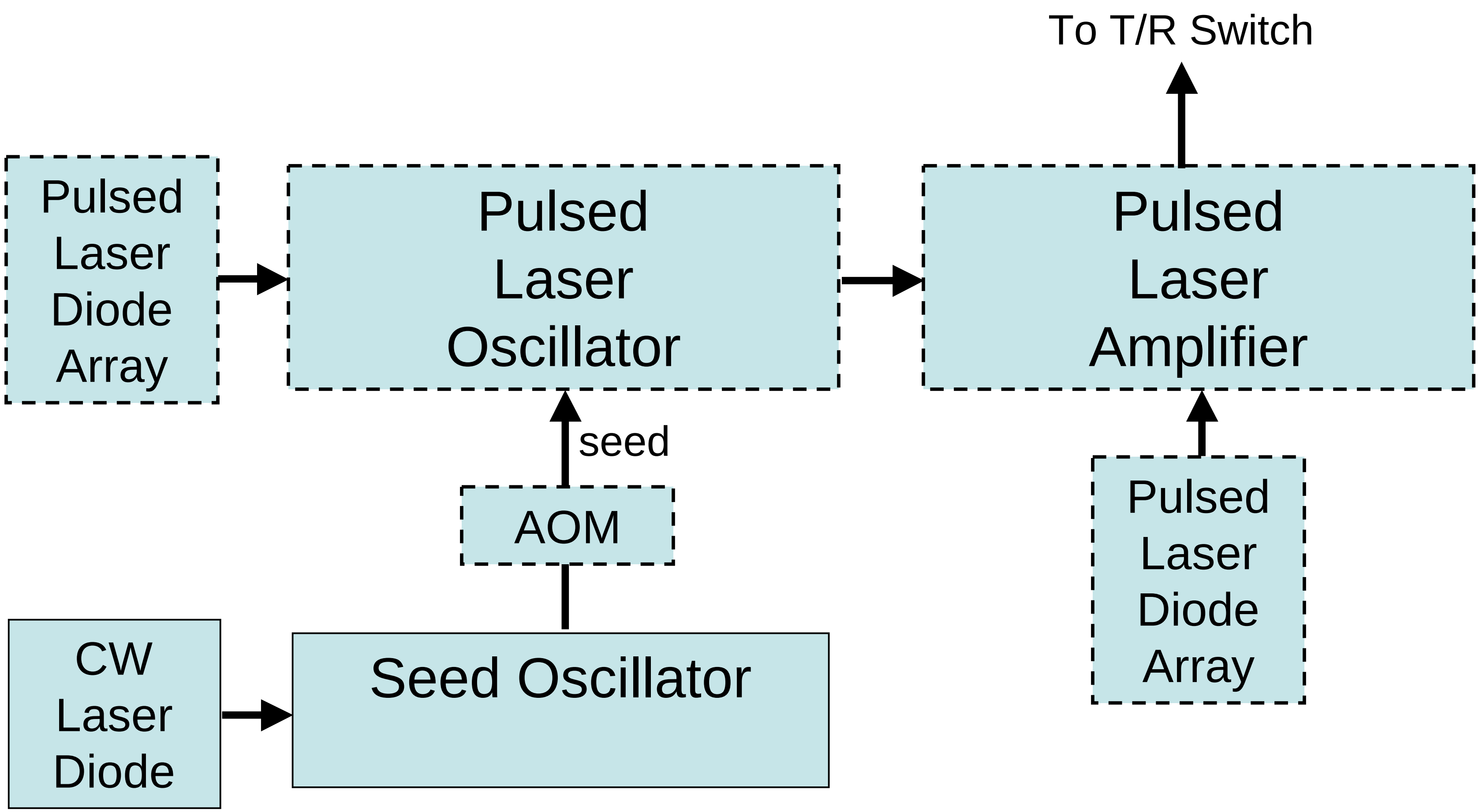
Pulsed Doppler Wind Lidar System



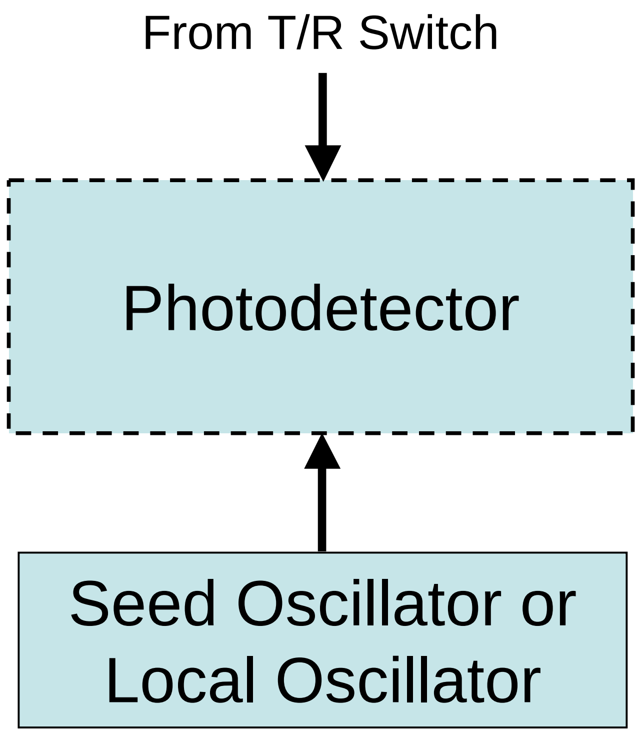
Lasers and Optics Portion



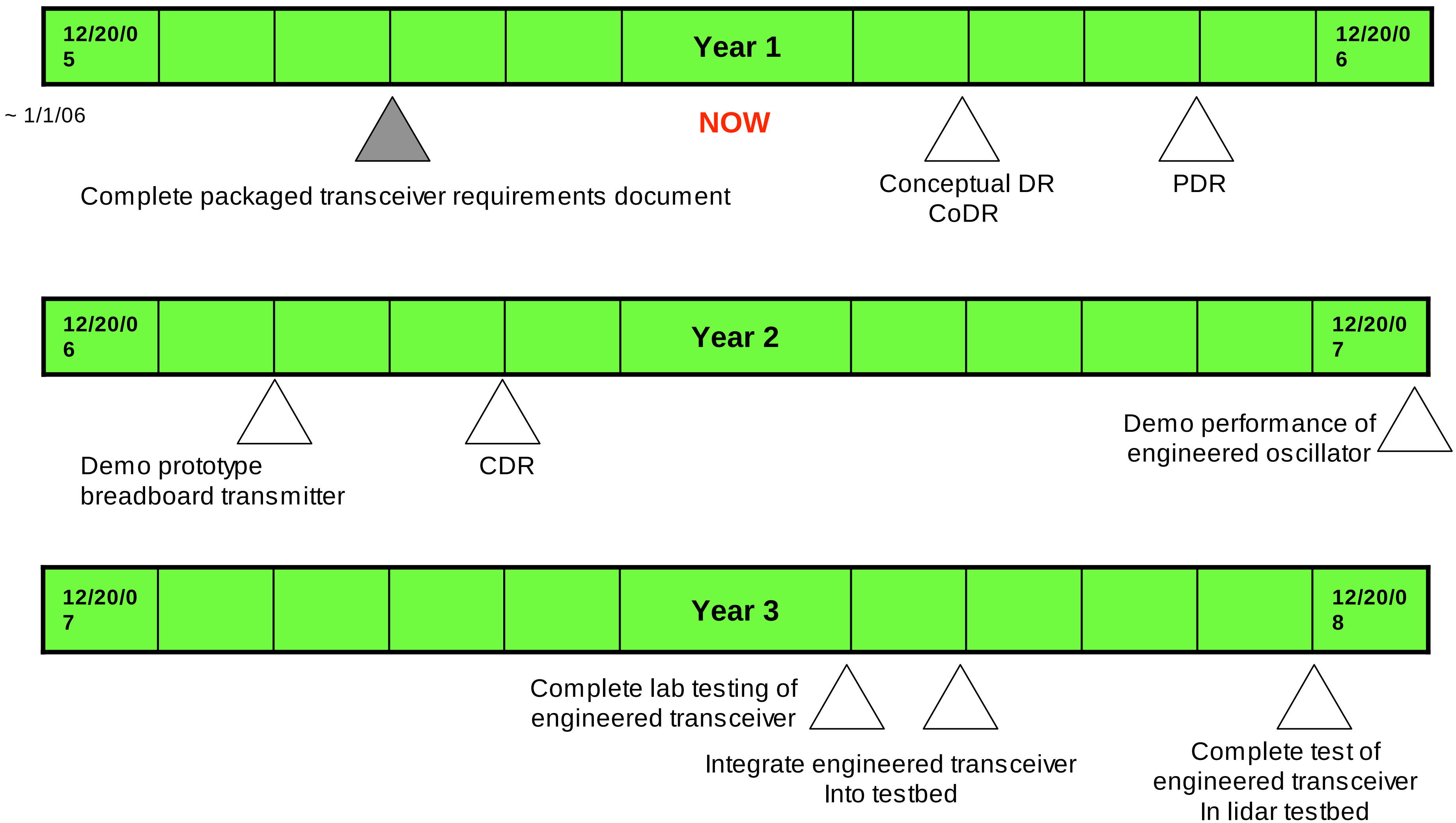
Transmitter Laser



Receiver

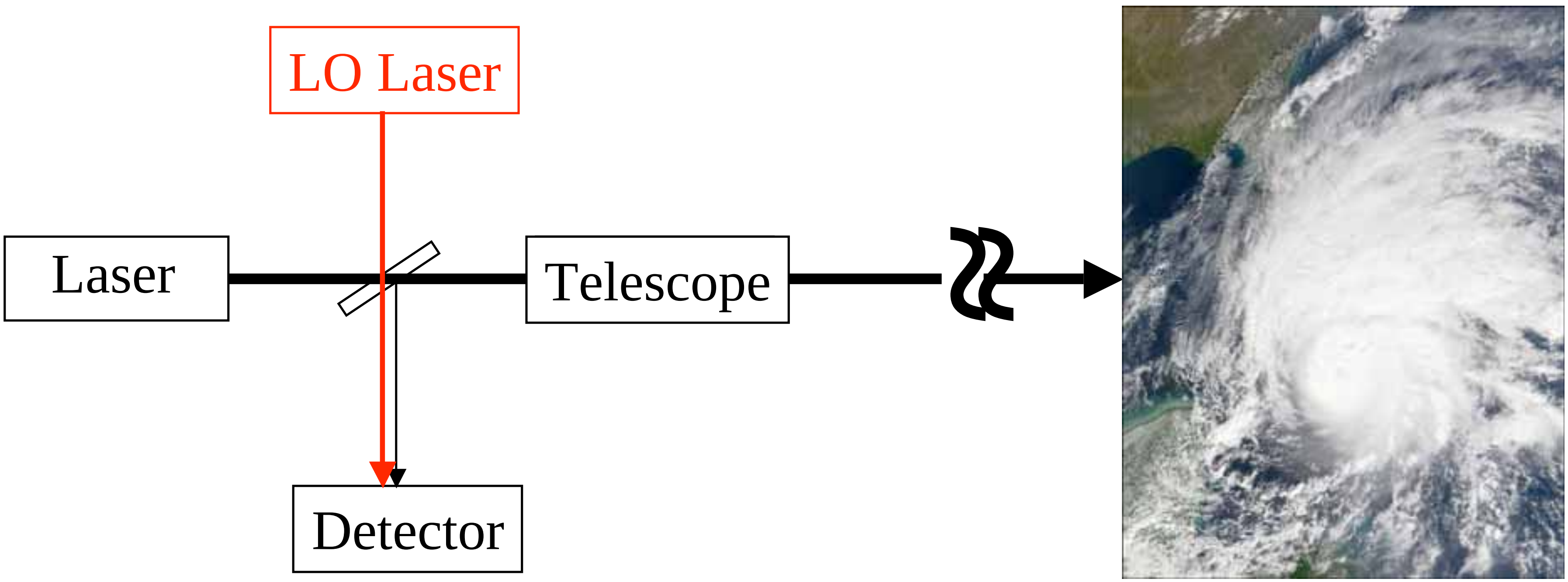

From T/R Switch
Photodetector
Seed Oscillator or
Local Oscillator

IIP- Milestones & Schedule



Coherent Doppler Wind Lidar Technique

What Is “Coherent” Lidar?



Benefits Of The LO Laser

- Heterodyne gain effectively eliminates signal shot noise, thermal or Johnson noise, dark-current noise, and amplifier noise. LO spatial filtering eliminates background light noise
- Translation of optical frequency to radio frequency allows signal processing with mature and flexible electronics and software, and reduces 1/f noise
- Extremely narrow bandpass filter using electronics or software rejects even more noise
- Frequency of beat signal is proportional to the target velocity - truly a direct measurement of velocity

Benefits Of The LO Laser

• High accuracy
• High photon efficiency
• No intensity measurements needed

"heterodyne detection can allow measurement of the phase of a single-frequency wave to a precision limited only by the uncertainty principle"

Michael A. Johnson and Charles H. Townes
Optics Communications 179, 183 (2000)

IIP Packaged Transceiver Requirements

Category	Requirement	Goal (if different) and/or Space Requirement	Reason
Laser Architecture	Master Oscillator Power Amplifier (MOPA)		High energy, beam quality, optical damage
Laser Material	Ho:Tm:LuLiF		High energy, high efficiency, atmospheric transmission
Nominal Wavelength	2.053472 microns		Atmospheric transmission
Pulse Energy	150 mJ	250 (space)	Computer modeling of measurement performance
Pulse Repetition Frequency	10 Hz	10-20 (space)	Shot accumulation, optimum laser diode array lifetime
Pulse Beam Quality	< 1.4 x diffraction limit		Heterodyne detection efficiency influence
Pulse Spectrum	Single Frequency	Few MHz (space)	Frequency estimation process
Injection seeding success	95%	99	Shot accumulation
Laser Heat Removal	Partial Conductively Cooled	FCC (space)	No liquid lines in space
Packaging	Compact, engineered	Aircraft ready Space qual. (space)	As ready as possible for aircraft follow on

Laser Design Considerations

- Laser wavelength
- Laser material
- Laser pumping geometry
- Laser cavity design
- Laser architecture

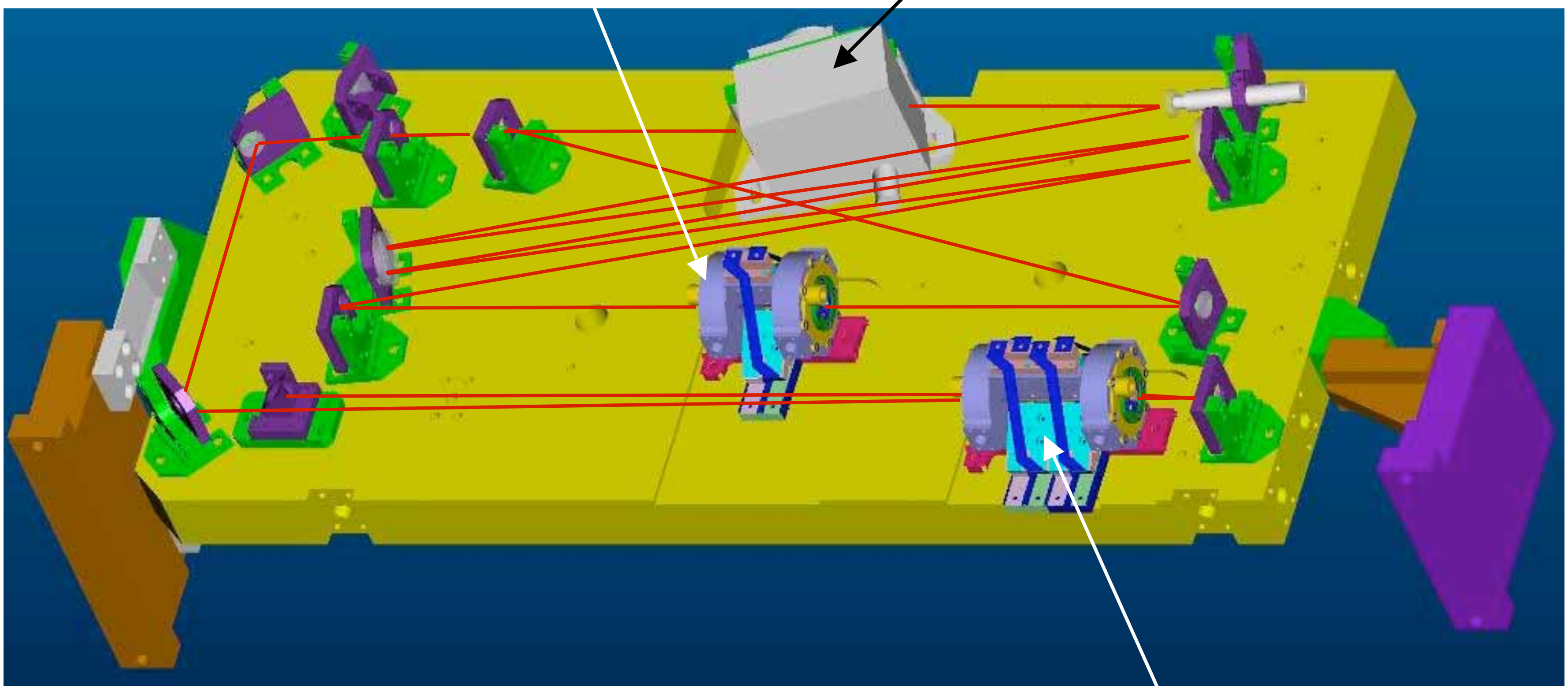
Oscillator cavity length

- Long cavity length is needed to obtain narrow linewidth
  - Pulse length is one of the critical parameters of a coherent Lidar.
  - A short pulse compromises frequency resolution while a long pulse compromises range resolution.
  - To meet the pulse length requirement, the oscillator length was changed from 2m to 3m. It prolongs the pulse width to near 200ns
  - The resonator has six mirrors and 8 bounces.

LRRP Pulsed, 2-Micron Laser Transmitter Opto-Mechanical Design

Oscillator Laser Head

AO Q-switch

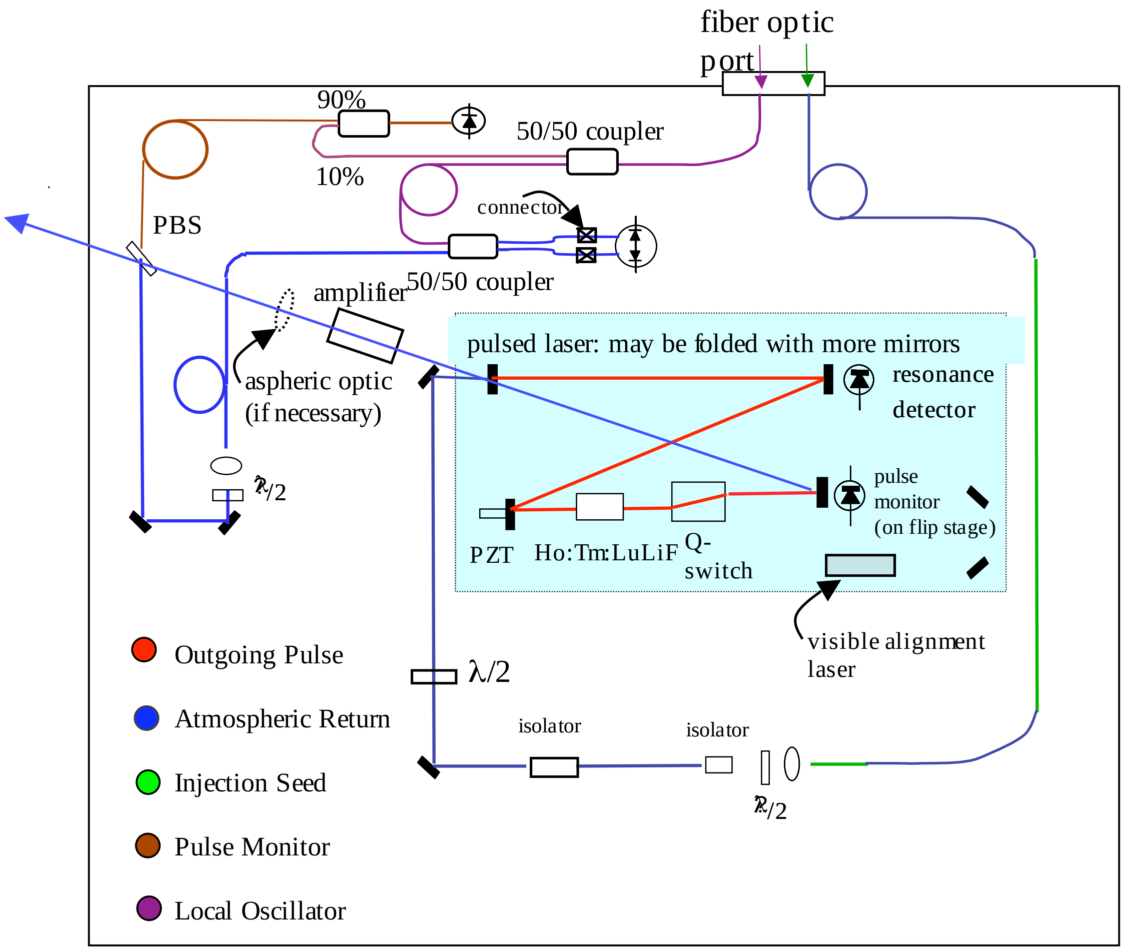


Amplifier Laser Head

- 3-m, bow-tie, unidirectional master oscillator-power amplifier
- Seeding and receiver optics on reverse side
- Expect this hardware in about 6 weeks for LRRP

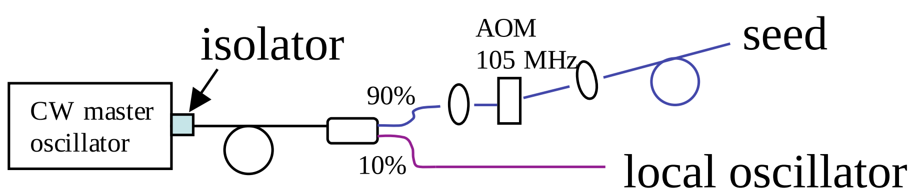
Proposed Transceiver “Box”

- Modular approach with injection seed & local oscillator separate from transceiver.
- Separate seed/LO allows flexibility to adapt to 3 measurements scenarios:
    - -simple, fixed frequency LO for ground or low platform speed.
    - - higher intermediate frequency for high platform speed
    - - swept LO for very high platform speed.
    - -DIAL of CO_2



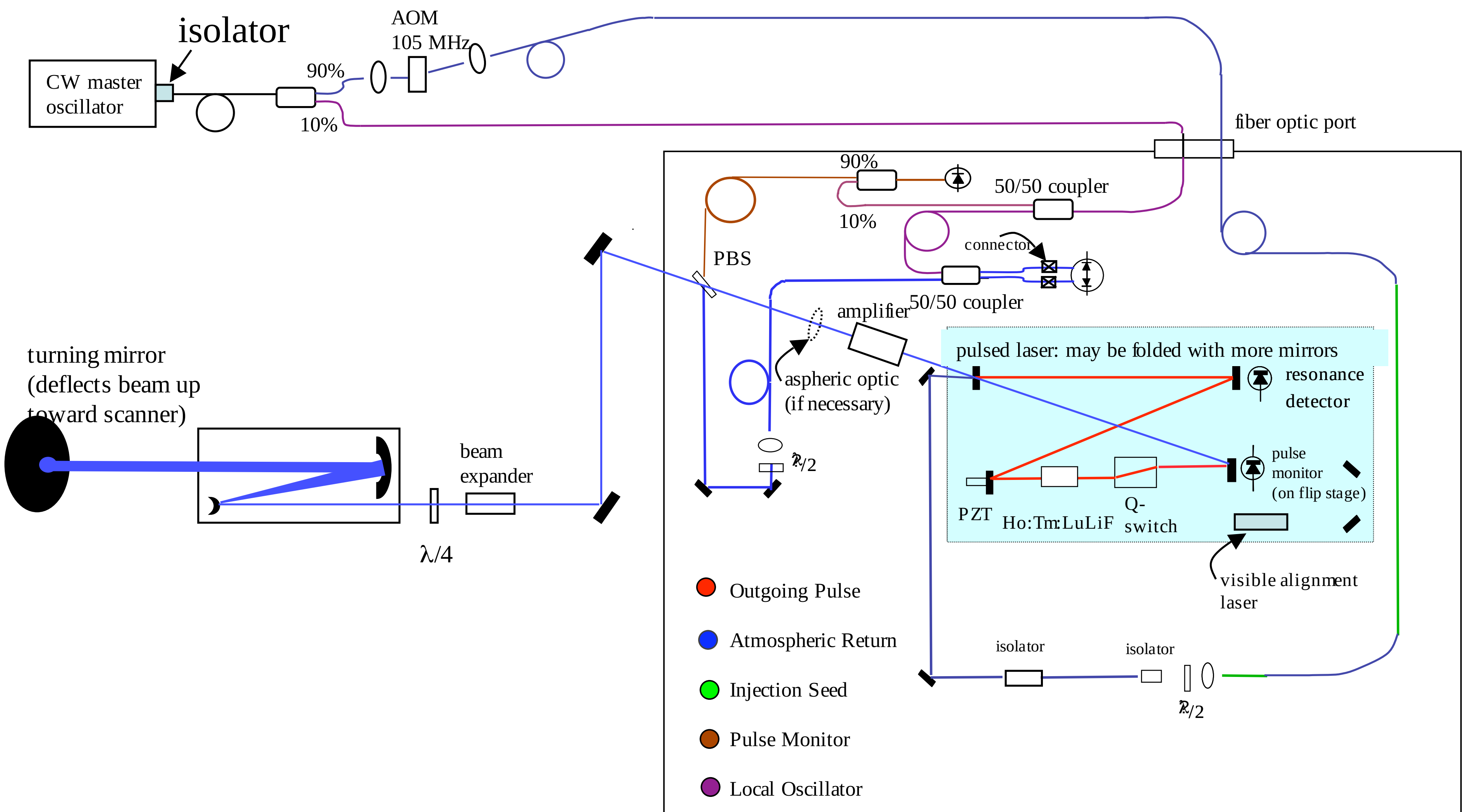
Note: only optical paths are represented; electrical and water paths are not shown.

Seed/LO Option 1

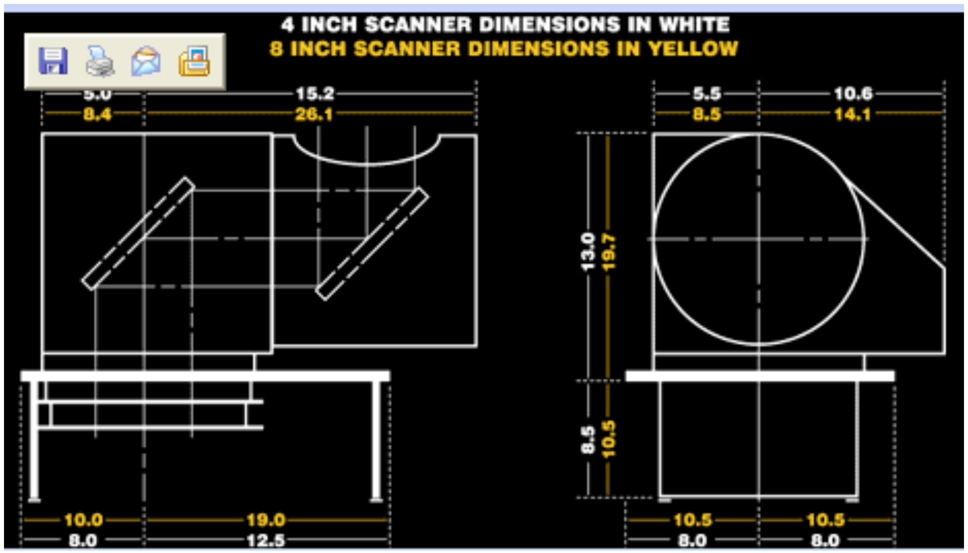


• baseline design for ground-based implementation.
• recommended for IIP demonstration.
• fiber-to-free space through AOM then back to fiber is disadvantageous—looking into fiber optic pigtailed AOM.
• could be packaged in rack-mount breadboard with fan for cooling (need thermal analysis).

Test Bed: Putting it all Together

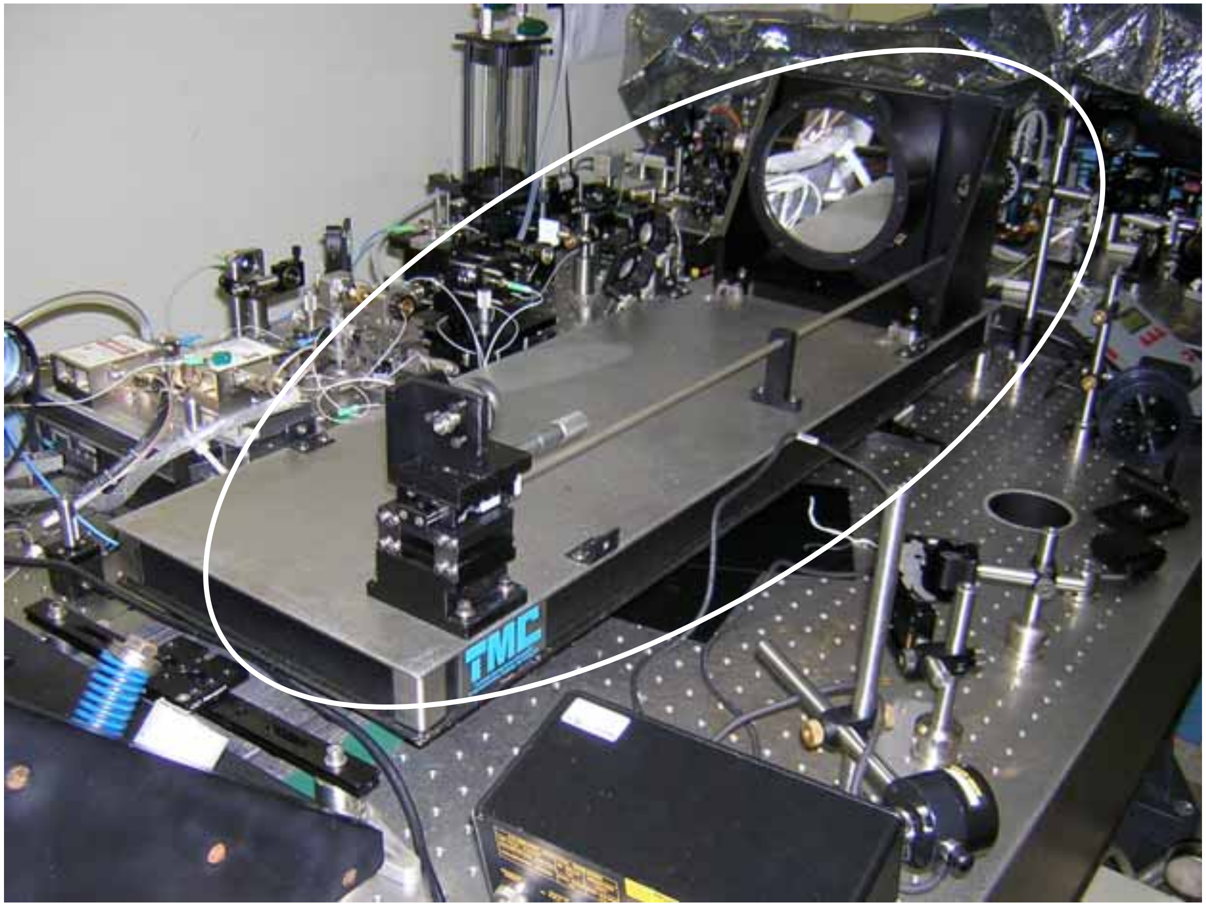


VALIDAR Scanner



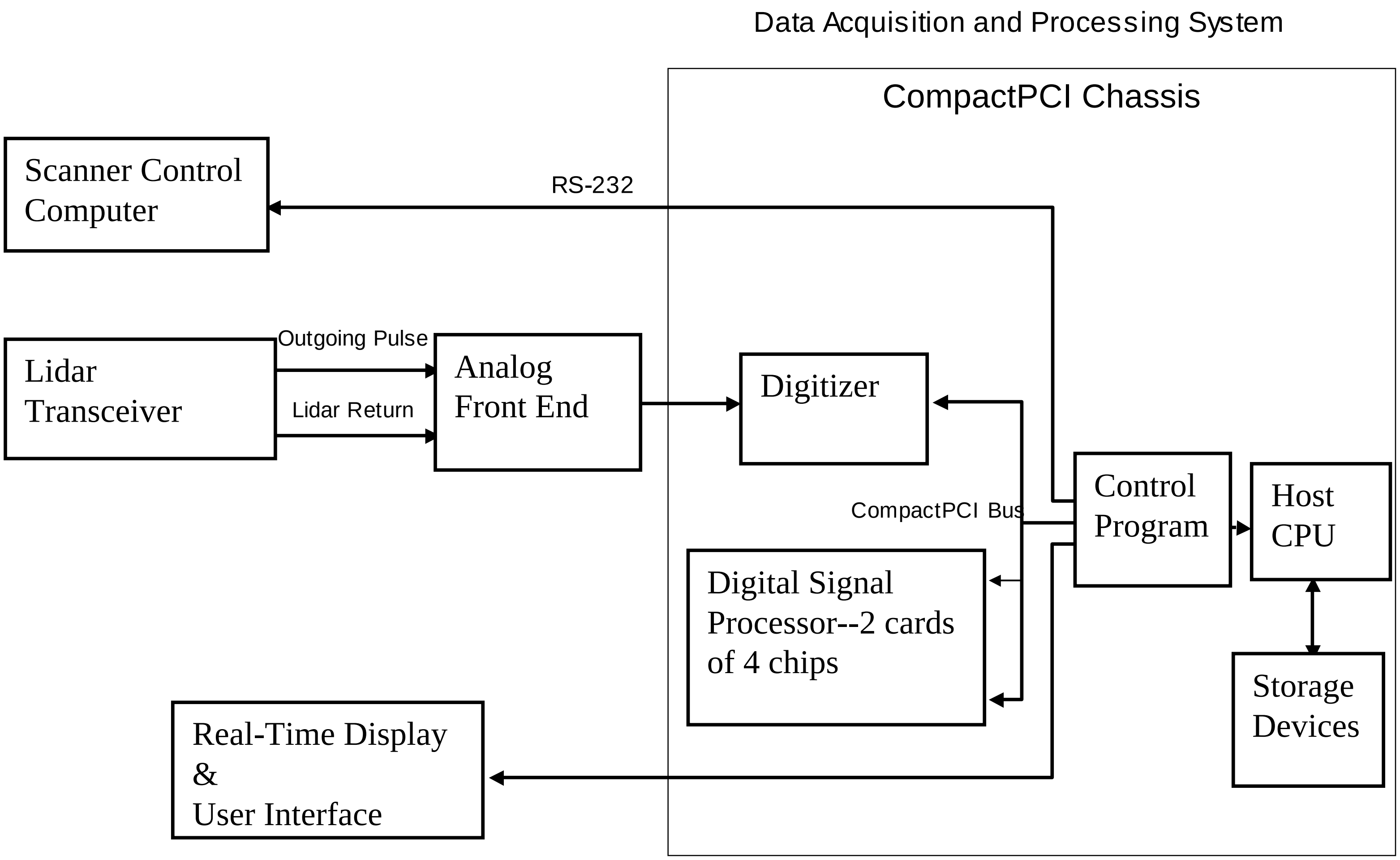
• scanner is mounted on roof of laboratory trailer.
• 8-inch clear aperture.
• can be pointed or scanned in elevation/azimuth for hemispherical coverage.
• linked to data acquisition computer for automated profiling of wind.

VALIDAR Telescope

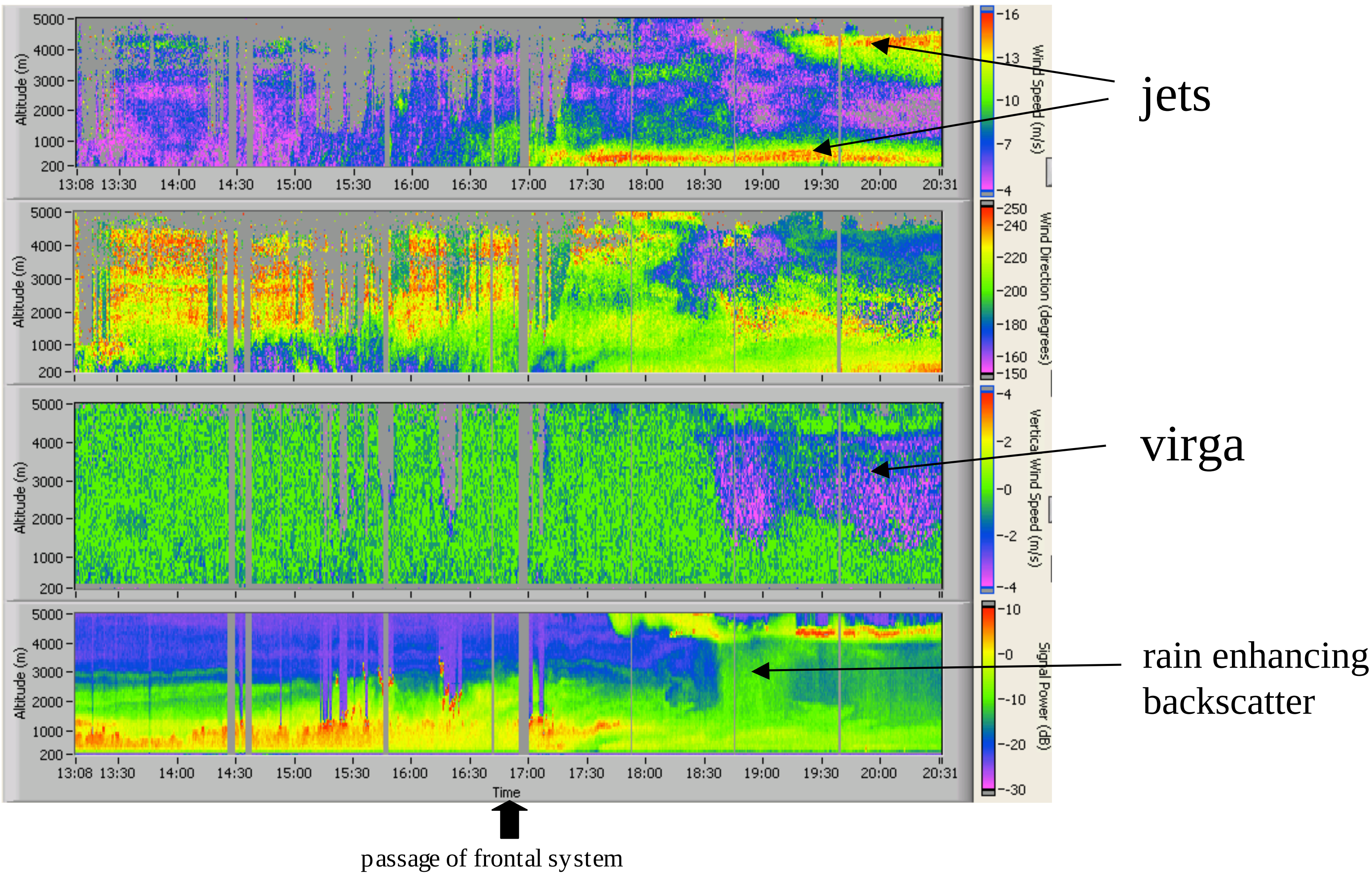


- off axis Dall-Kirkham design.
- 6-inch aperture
- 20X expansion

Data Acquisition and Processing (already built)



Atmospheric Measurements (will be better than this VALIDAR sample)



Summary

- IIP project 6 months into 36 month effort
- Leveraging LRRP work on compact laser in 05 and 06
- Plan on significant steps of compact, engineered packaging of state-of-the-art laser/lidar technology. TRL definitions do not reveal significant progress.
- Companion IIP at GSFC for noncoherent Doppler wind lidar will complement this project to permit hybrid DWL on aircraft and then in space
- Project very consistent with findings of NASA/ESTO Laser/Lidar Technology Requirements Working Group results (FY06). To be issued in final report
- Anticipate strong endorsement of global winds by NAS decadal study on earth sciences
- Same technology promises additional applications for earth and Mars